In The Claims

What is claimed is:

Claim 1 (canceled)

Claim 2 (currently amended): The system estimation method according to claim ~~1~~7 ~~or 9 or 11~~, wherein the processing section calculates the existence condition in accordance with a following expression:

$$\hat{\boldsymbol{\Sigma}}_{i|i}^{-1} = \hat{\boldsymbol{\Sigma}}_{i|i-1}^{-1} + \frac{1-\gamma_f^{-2}}{\rho}\boldsymbol{H}_i^T\boldsymbol{H}_i > 0, \quad i = 0, \ldots, k \tag{17}$$

Claim 3 (currently amended): The system estimation method according to claim ~~1~~7, wherein the processing section calculates the existence condition in accordance with a following expression:

$$-\varrho\hat{\Xi}_i + \rho\gamma_f^2 > 0, \quad i = 0, \cdots, k \tag{18}$$

here,

$$\varrho = 1-\gamma_f^2, \quad \hat{\Xi}_i = \frac{\rho\boldsymbol{H}_i\boldsymbol{K}_{s,i}}{1-\boldsymbol{H}_i\boldsymbol{K}_{s,i}}, \quad \rho = 1-\chi(\gamma_f) \tag{19}$$

where the forgetting factor ρ and the upper limit value γ_f have a following relation:

$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotonically damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.

Claims 4-6 (canceled)

Claim 7 (currently amended): ~~The system estimation method according to claim 1, wherein at the step of executing the hyper H_∞ filter,~~

~~the processing section calculates the~~A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions (20) to (22), or, expression (20) and expressions which are deleted J_1^{-1} and J_1 in the expressions (21) and (22),:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \quad (20)$$

$$K_{s,k} = K_k(:,1)/R_{e,k}(1,1)\ ,\ K_k = \rho^{\frac{1}{2}}(\rho^{-\frac{1}{2}}K_k R_{e,k}^{-\frac{1}{2}}J_1^{-1})J_1 R_{e,k}^{\frac{1}{2}} \quad (21)$$

$$\left[\begin{array}{c|c} R_k^{\frac{1}{2}} & C_k\hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \\ \hline 0 & \rho^{-\frac{1}{2}}\hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \end{array}\right]\Theta(k) = \left[\begin{array}{c|c} R_{e,k}^{\frac{1}{2}} & 0 \\ \hline \rho^{-\frac{1}{2}}K_k R_{e,k}^{-\frac{1}{2}}J_1^{-1} & \hat{\Sigma}_{k+1|k}^{\frac{1}{2}} \end{array}\right] \quad (22)$$

Where,

$$R_k = R_k^{\frac{1}{2}}J_1R_k^{\frac{T}{2}},\ R_k^{\frac{1}{2}} = \begin{bmatrix} \rho^{\frac{1}{2}} & 0 \\ 0 & \rho^{\frac{1}{2}}\gamma_f \end{bmatrix},\ J_1 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix},\ \hat{\Sigma}_{k|k-1} = \hat{\Sigma}_{k|k-1}^{\frac{1}{2}}\hat{\Sigma}_{k|k-1}^{\frac{T}{2}}$$

$$R_{e,k} = R_k + C_k\hat{\Sigma}_{k|k-1}C_k^T,\ C_k = \begin{bmatrix} H_k \\ H_k \end{bmatrix},\ R_{e,k} = R_{e,k}^{\frac{1}{2}}J_1R_{e,k}^{\frac{T}{2}},\ \hat{x}_{0|0} = \check{x}_0 \quad (23)$$

$\Theta(k)$ denotes a J-unitary matrix, that is, satisfies $\Theta(k)J\Theta H(k)^T = J$, $J = (J_1 \oplus I)$, I denotes a unit matrix, $K_k(:,1)$ denotes a column vector of a first column of the matrix K_k.

~~wherein J_1^{-1} and J_1 can be deleted in the expressions (21) and (22),~~

here,

$x\hat{}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

y_k: the observation signal,

F_k: the dynamics of the system,

$K_{s,k}$: the filter gain,

H_k: the observation matrix,

$\Sigma^{\wedge}_{k|k}$: corresponding to a covariance matrix of an error of $x^{\wedge}_{k|k}$,

$\Theta(k)$: the J-unitary matrix, and

$R_{e,k}$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

Claim 8(currently amended: The system estimation method according to claim 7, wherein the step of executing the hyper H_∞ filter includes:

a step at which the processing section calculates ~~K_k and~~ $\Sigma^{\wedge}_{k+1|k}{}^{1/2}$ by using the expression (22);

a step at which the processing section calculates the filter gain $K_{s,k}$ based on ~~the~~an initial condition ~~and~~ of $\Sigma^{\wedge}_{k|k-1}$ and an initial condition of C_k~~, and the matrix gain k_k~~ by using the expression (21);

a step at which the processing section updates a filter equation of the H_∞ filter of the expression (20); and

a step at which the processing section repeatedly executes ~~the respective steps~~the step of calculating by using the expression (20), the step of calculating by using the expression (21)and, the step of updating while advancing the time k.

Claim 9 (currently amended): ~~The system estimation method according to claim 1, wherein at the step of executing the hyper H_∞ filter,~~

~~the processing section~~ A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a

filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains ~~the~~ a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \quad (61)$$

$$K_{s,k} = K_k(:,1)/R_{e,k}(1,1)\ ,\ K_k = \rho^{\frac{1}{2}}(\overline{K}_k R_{e,k}^{-\frac{1}{2}}) R_{e,k}^{\frac{1}{2}} \quad (62)$$

$$\begin{bmatrix} R_{e,k+1}^{\frac{1}{2}} & 0 \\ \begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} R_{e,k+1}^{-\frac{T}{2}} J_1 & \tilde{L}_{k+1} R_{r,k+1}^{-\frac{T}{2}} \end{bmatrix} = \begin{bmatrix} R_{e,k}^{\frac{1}{2}} & \check{C}_{k+1} \tilde{L}_k R_{r,k}^{-\frac{1}{2}} \\ \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-\frac{1}{2}} J_1 & \rho^{-\frac{1}{2}} \tilde{L}_k R_{r,k}^{-\frac{1}{2}} \end{bmatrix} \Theta(k) \quad (63)$$

here, $\Theta(k)$ denotes an arbitrary J-unitary matrix, and $\check{C}_k = \check{C}_{k+1}\Psi$ is established, where

$$R_k = R_k^{\frac{1}{2}} J_1 R_k^{\frac{T}{2}},\ \ R_k^{\frac{1}{2}} = \begin{bmatrix} \rho^{\frac{1}{2}} & 0 \\ 0 & \rho^{\frac{1}{2}}\gamma_f \end{bmatrix},\ J_1 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix},\ \hat{\Sigma}_{k|k-1} = \hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \hat{\Sigma}_{k|k-1}^{\frac{T}{2}}$$

$$R_{e,k} = R_k + C_k \hat{\Sigma}_{k|k-1} C_k^T,\ \ C_k = \begin{bmatrix} H_k \\ H_k \end{bmatrix},\ R_{e,k} = R_{e,k}^{\frac{1}{2}} J_1 R_{e,k}^{\frac{T}{2}},\ \ \hat{x}_{0|0} = \check{x}_0 \quad (23)$$

---

here,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

y_k: the observation signal,

$K_{s,k}$: the filter gain,

H_k: the observation matrix,

$\Theta(k)$: the J-unitary matrix, and

$R_{e,k}$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

Claim 10 (currently amended): The system estimation method according to claim 9, wherein the step of executing the hyper H_∞ filter includes:

a step at which the processing section calculates $\breve{K}_k$ based on an initial condition of $R_{e,k+1}$, $R_{r,k+1}$ and $\breve{L}_{k+1}$ by using the expression (63);

a step at which the processing section calculates the filter gain ~~$\breve{K}_{s,k}$~~ $K_{s,k}$ based on the initial condition and by using the expression (62);

a step at which the processing section updates a filter equation of the H_∞ filter of the expression (61); and

a step at which the processing section repeatedly executes ~~the respective steps~~the step of calculating by using the expression (63), the step of calculating by using the expression (62), and, the step of updating while advancing the time k.

Claim 11 (currently amended): ~~The system estimation method according to claim 1, wherein at the step of executing the hyper H_∞ filter,~~

~~the processing section~~ A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage

section and obtains ~~the~~ a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix $\bar{K}_k$ and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \tag{25}$$

$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \tag{26}$$

$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{27}$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{28}$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{29}$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T\check{C}_{k+1}^T R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{30}$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix},\quad \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k],\quad \check{H}_1 = [u(1),0,\ldots,0]$$

$$R_{e,1} = R_1 + \check{C}_1\check{\Sigma}_{1|0}\check{C}_1^T,\quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix},\quad \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2,\rho^3,\ldots,\rho^{N+2}\},\quad \rho = 1-\chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2},\quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix},\quad \overline{K}_0 = 0,\quad \hat{x}_{0|0} = \check{x}_0,\quad \overline{K}_k = \rho^{-\frac{1}{2}}K_k \tag{31}$$

~~wherein the above expressions can be arranged also with respect to K_k instead of $\bar{K}_k$,~~

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $\bar{K}_k$, and

$R_{e,k}$, $\tilde{L}_k$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

Claim 12 (canceled)

Claim 13 (currently amended): The system estimation method according to claim ~~1~~7, wherein an estimated value $z^{v}_{k|k}$ of the output signal is obtained from the state estimated value $x^{\wedge}_{k|k}$ at the time k by a following expression:

$z^{v}_{k|k} = H_k x^{\wedge}_{k|k}$.

Claim 14 (currently amended): The system estimation method according to claim ~~1~~7, wherein the H_∞ filter equation is applied to obtain the state estimated value $x^{\wedge}_{k|k}=[h^{\wedge}_1[k],\square\square\square, h^{\wedge}_N[k]]$

a pseudo-echo is estimated by a following expression:

$$\hat{d}_k = \sum_{i=0}^{N-1} \hat{h}_i[k] u_{k-i}, \quad k = 0, 1, 2, \cdots \tag{34}$$

and

an echo canceller is realized by canceling an actual echo by the obtained pseudo-echo.

Claim 15 (currently amended): A system estimation program for causing a computer to make state estimation robust and to

optimize a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

~~for a state space model expressed by following expressions:~~

$\cancel{x_{k+1} = F_k x_k + G_k w_k}$

$\cancel{y_k = H_k x_k + v_k}$

$\cancel{z_k = H_k x_k}$

~~here,~~

~~x_k: a state vector or simply a state,~~

~~w_k: a system noise,~~

~~v_k: an observation noise,~~

~~y_k: an observation signal,~~

~~z_k: an output signal,~~

~~F_k: dynamics of a system, and~~

~~G_k: a drive matrix,~~

~~a maximum energy gain to a filter error from a disturbance weighted with the forgetting coefficient ρ as an evaluation criterion is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and~~

the system estimation program causes the computer to execute:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K^{-}_{k} and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \quad (25)$$
$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \quad (26)$$
$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T \check{C}_{k+1}^T \quad (27)$$
$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \quad (28)$$
$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T \check{C}_{k+1}^T \quad (29)$$
$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \check{C}_{k+1}^T R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \quad (30)$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k], \quad \check{H}_1 = [u(1), 0, \ldots, 0]$$
$$R_{e,1} = R_1 + \check{C}_1\check{\Sigma}_{1|0}\check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$
$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \overline{K}_0 = 0, \quad \hat{x}_{0|0} = \check{x}_0, \quad \overline{K}_k = \rho^{-\frac{1}{2}}K_k \quad (31)$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$x\hat{}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $K\bar{}_k$, and

$R_{e,k}$, $L\tilde{}_k$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence

condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

~~a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;~~

~~a step at which the processing section determines the forgetting coefficient ρ relevant to the state space model in accordance with the upper limit value γ_f;~~

~~a step at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and uses the forgetting coefficient ρ to execute a hyper H_∞ filter expressed by a following expression:~~

$\cancel{\hat{x}_{k|k} = F_{k-1}\hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_kF_{k-1}\hat{x}_{k-1|k-1})}$

~~here,~~

~~$\hat{x}_{k|k}$: an estimated value of a state x_k at a time k using observation signals y_0 to y_k,~~

~~F_k: dynamics of the system, and~~

~~$K_{s,k}$: a filter gain,~~

~~a step at which the processing section stores an obtained value relating to the hyper H_∞ filter into the storage section;~~

~~a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting coefficient ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$; and~~

~~a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into~~

~~the storage section by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.~~

Claim 16 (currently amended): A computer readable recording medium recording a system estimation program for causing a computer to make state estimation robust and to optimize a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

~~for a state space model expressed by following expressions:~~

$\cancel{x_{k+1} = F_k x_k + G_k w_k}$

$\cancel{y_k = H_k x_k + v_k}$

$\cancel{z_k = H_k x_k}$

~~here,~~

~~x_k: a state vector or simply a state,~~

~~w_k: a system noise,~~

~~v_k: an observation noise,~~

~~y_k: an observation signal,~~

~~z_k: an output signal,~~

~~F_k: dynamics of a system, and~~

~~G_k: a drive matrix,~~

~~a maximum energy gain to a filter error from a disturbance weighted with the forgetting coefficient ρ as an evaluation criterion is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and~~

the computer readable recording medium recording the system estimation program causes the computer to execute:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K^{-}_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \tag{25}$$
$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \tag{26}$$
$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{27}$$
$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{28}$$
$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{29}$$
$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T\check{C}_{k+1}^T R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{30}$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k], \quad \check{H}_1 = [u(1), 0, \ldots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1\check{\Sigma}_{1|0}\check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \overline{K}_0 = 0, \quad \hat{x}_{0|0} = \check{x}_0, \quad \overline{K}_k = \rho^{-\frac{1}{2}}K_k \tag{31}$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$x\hat{}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $K\bar{}_k$, and

$R_{e,k}$, $L\tilde{}_k$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence

condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter. ~~a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;~~

~~a step at which the processing section determines the forgetting coefficient ρ relevant to the state space model in accordance with the upper limit value γ_f;~~

~~a step at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and uses the forgetting coefficient ρ to execute a hyper H_∞ filter expressed by a following expression:~~

$\cancel{\hat{x}_{k|k} = F_{k-1}\hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k F_{k-1}\hat{x}_{k-1|k-1})}$

~~here,~~

~~$\hat{x}_{k|k}$: an estimated value of a state x_k at a time k using observation signals y_0 to y_k,~~

~~F_k: dynamics of the system, and~~

~~$K_{s,k}$: a filter gain,~~

~~a step at which the processing section stores an obtained value relating to the hyper H_∞ filter into the storage section;~~

~~a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting coefficient ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$; and~~

~~a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into~~

~~the storage section by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.~~

Claim 17 (currently amended): A system estimation device for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

~~for a state space model expressed by following expressions:~~

$\cancel{x_{k+1} = F_k x_k + G_k w_k}$

$\cancel{y_k = H_k x_k + v_k}$

$\cancel{z_k = H_k x_k}$

~~here,~~

~~x_k: a state vector or simply a state,~~

~~w_k: a system noise,~~

~~v_k: an observation noise,~~

~~y_k: an observation signal,~~

~~z_k: an output signal,~~

~~F_k: dynamics of a system, and~~

~~G_k: a drive matrix,~~

~~a maximum energy gain to a filter error from a disturbance weighted with the forgetting coefficient ρ as an evaluation criterion is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f,~~

the system estimation device comprises:

a processing section to execute the estimation algorithm; and

a storage section to which reading and/or writing is performed by the processing section and which stores respective observed values, set values, and estimated values relevant to the state space model,

further comprising:

a means at which the processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from the storage section or an input section;

a means at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a means of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K^{-}_{k} and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \tag{25}$$

$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \tag{26}$$

$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T \breve{C}_{k+1}^T \tag{27}$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\breve{C}_{k+1}\tilde{L}_k \tag{28}$$

$$R_{e,k+1} = R_{e,k} - \breve{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T \breve{C}_{k+1}^T \tag{29}$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \breve{C}_{k+1}^T R_{e,k}^{-1}\breve{C}_{k+1}\tilde{L}_k \tag{30}$$

Where,

$$\breve{C}_{k+1} = \begin{bmatrix} \breve{H}_{k+1} \\ \breve{H}_{k+1} \end{bmatrix}, \quad \breve{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k], \quad \breve{H}_1 = [u(1), 0, \ldots, 0]$$

$$R_{e,1} = R_1 + \breve{C}_1\breve{\Sigma}_{1|0}\breve{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix}, \quad \breve{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \overline{K}_0 = 0, \quad \hat{x}_{0|0} = \check{x}_0, \quad \overline{K}_k = \rho^{-\frac{1}{2}}K_k \tag{31}$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$x\hat{}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $K\bar{}_k$, and

$R_{e,k}$, $L\tilde{}_k$: an auxiliary variable.

a means at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a means at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a means at which the processing section sets the upper limit value to be small within a range where the existence

condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the means of executing the hyper H_∞ filter.

~~the processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section,~~

~~the processing section determines the forgetting coefficient ρ relevant to the state space model in accordance with the upper limit value γ_f,~~

~~the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and uses the forgetting coefficient ρ to execute a hyper H_∞ filter expressed by a following expression:~~

$\cancel{\hat{x}_{k|k} = F_{k-1}\hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k F_{k-1}\hat{x}_{k-1|k-1})}$

~~here,~~

~~$\hat{x}_{k|k}$; an estimated value of a state x_k at a time k using observation signals y_0 to y_k,~~

~~F_k: dynamics of the system, and~~

~~$K_{s,k}$; a filter gain,~~

~~the processing section stores an obtained value relating to the hyper H_∞ filter into the storage section,~~

~~the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting coefficient ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and~~

~~the processing part sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.~~

Claim 18 (new): The system estimation method according to claim 9, wherein the processing section calculates the existence condition in accordance with a following expression:

$$-\varrho\hat{\Xi}_i \;+\; \rho\gamma_f^2 > 0, \quad i = 0, \cdots, k \tag{18}$$

here,

$$\varrho \;=\; 1-\gamma_f^2, \quad \hat{\Xi}_i = \frac{\rho \boldsymbol{H}_i \boldsymbol{K}_{s,i}}{1-\boldsymbol{H}_i \boldsymbol{K}_{s,i}}, \quad \rho = 1-\chi(\gamma_f) \tag{19}$$

where the forgetting factor ρ and the upper limit value γ_f have a following relation:

$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotonically damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.

Claim 19 (new): The system estimation method according to claim 9, wherein an estimated value $z^{v}_{k|k}$ of the output signal is obtained from the state estimated value $x^{\wedge}_{k|k}$ at the time k by a following expression:

$z^{v}_{k|k} = H_k x^{\wedge}_{k|k}$.

Claim 20 (new): The system estimation method according to claim 9, wherein the H_∞ filter equation is applied to obtain the state estimated value $x^{\wedge}_{k|k}=[h^{\wedge}_1[k],\square\square\square, h^{\wedge}_N[k]]$

a pseudo-echo is estimated by a following expression:

$$\hat{d}_k \;=\; \sum_{i=0}^{N-1} \hat{h}_i[k] u_{k-i}, \quad k = 0, 1, 2, \cdots \tag{34}$$

and

an echo canceller is realized by canceling an actual echo by the obtained pseudo-echo.

Claim 21 (new): The system estimation method according to claim 11, wherein the processing section calculates the existence condition in accordance with a following expression:

$$-\varrho\hat{\Xi}_i \ + \ \rho\gamma_f^2 > 0, \quad i = 0, \cdots, k \tag{18}$$

here,

$$\varrho \ = \ 1-\gamma_f^2, \quad \hat{\Xi}_i = \frac{\rho \boldsymbol{H}_i \boldsymbol{K}_{s,i}}{1-\boldsymbol{H}_i \boldsymbol{K}_{s,i}}, \quad \rho = 1-\chi(\gamma_f) \tag{19}$$

where the forgetting factor ρ and the upper limit value γ_f have a following relation:

$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotonically damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.

Claim 22 (new): The system estimation method according to claim 11, wherein an estimated value $z^v_{k|k}$ of the output signal is obtained from the state estimated value $x^\wedge_{k|k}$ at the time k by a following expression:

$z^v_{k|k} = H_k x^\wedge_{k|k}$.

Claim 23 (new): The system estimation method according to claim 11, wherein the H_∞ filter equation is applied to obtain the state estimated value $x^\wedge_{k|k}=[h^\wedge_1[k],\square\square\square, h^\wedge_N[k]]$

a pseudo-echo is estimated by a following expression:

$$\hat{d}_k \ = \ \sum_{i=0}^{N-1} \hat{h}_i[k] u_{k-i}, \quad k = 0, 1, 2, \cdots \tag{34}$$

and

an echo canceller is realized by canceling an actual echo by the obtained pseudo-echo.